electronics

CLEVELAND INSTITUTE OF ELECTRONICS / CLEVELAND, OHIO

Electronics and Your Slide Rule Part II

An AUTO-PROGRAMMED™ Lesson

ABOUT THE AUTHOR

Through over 15 years experience in helping students learn through home study, Mr. Geiger has obtained an intimate understanding of the problems facing home-study students. He has used this knowledge to make many improvements in our teaching methods. Mr. Geiger knows that students learn fastest when they actively participate in the lesson, rather than just reading it. Accordingly, you will find many "What Have You Learned?" sections in this lesson, to assist you in getting a firm grasp of each topic.

Mr. Geiger edits much of our new lesson material, polishing up the manuscripts we receive from subject-matter experts so that they are easily readable, contain only training useful to the student in practical work, and are written so as to teach, rather than merely presenting information.

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Electronics and Your Slide Rule

Combined Operations with Electronic Applications

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In this lesson you will learn...

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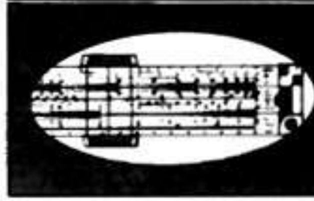


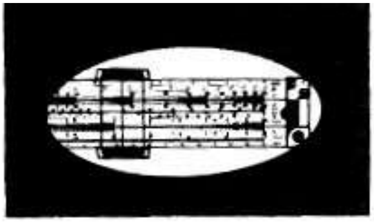
A chat with your instructor

Some people think they know how to use a slide rule if they can multiply or divide two numbers with it. While a slide rule can be helpful even if that is all one knows about it, the real potential of a slide rule as a time saving device is realized in problems involving several steps. Rather than working such a problem step-by-step and reading off the answer to each before starting the following step, the expert combines the steps into one blended operation. The only reading he generally makes is the final answer. This lesson will teach you the way of the expert.

In the last lesson you learned the basic use of the C and D scales. In this lesson you will be introduced to three additional scales, the CI, the A and the B. While the CI scale is basically one for finding reciprocals, you will learn how it is used in conjunction with other scales to simplify many problems. The A and B scales are basically for squares and square roots. By combining these scales with other scales, you can solve problems quickly that would involve several steps if worked by pencil.

We have emphasized before that you need pay no attention to the decimal point in the number while manipulating the slide rule. There is one very important exception. That is problems where square roots are involved. While studying this lesson pay particular attention to how the decimal point location affects the method of taking square root.

You will also learn in this lesson the use of the slide rule for problems in proportion. Proportional problems are particularly easy to understand and work by the slide rule method, and such problems are widely found in electronics.



Electronics and Your Slide Rule Part II

15 RECIPROCALS...The reciprocal of a number is that number divided into 1. Thus the reciprocal of 245 is equal to 1/245, which by regular division on the slide rule is found to be 0.00408. However, since reciprocals are so widely used, the CI scale is placed on the slide rule so that reciprocal values can be read directly. To find the reciprocal of 245 using the CI scale, set the hairline of the indicator over 245 on scale C and then read the digits of the answer, 408 under the hairline on the CI scale. See Fig. 14. The slide need not be moved in finding reciprocals. To locate the decimal point, notice that 1/200 is equal to 0.005. Hence, the correct answer must be 0.00408.

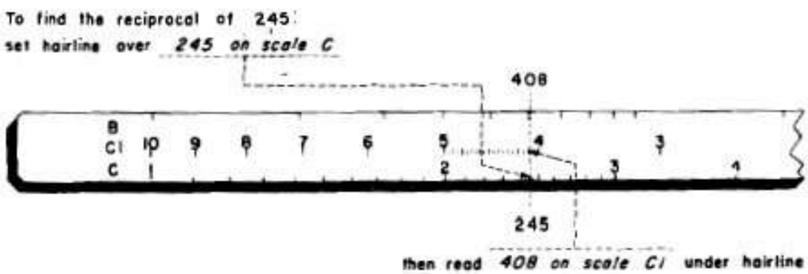


Fig. 14. Reading reciprocal of 245, which equals 0.00408, on slide rule.

WHAT HAVE YOU LEARNED?

Find the reciprocals of the following values:

1...0.173	5...0.00064
2...2.849	6...32,000
3...87	7...33.6
4...0.4444	8...4.15×10^{-8}

9...The conductance of a circuit is 0.72 mhos. What is its resistance?

10...Four resistors of 24, 130, 45, and 73 ohms are connected in parallel. What is the combined resistance?

11...Three resistors of 18, 32, and 26 ohms are connected in parallel. What is the combined resistance?

ANSWERS

1. 5.78 2. 0.351 3. 0.01149 4. 2.25 5. 1562
6. 0.0000312 7. 0.0298 8. 2.41×10^7 9. 1.389 ohms
10. 11.73 ohms 11. 7.98 ohms

16 COMBINED MULTIPLICATION AND DIVISION...By handling problems where both multiplication and division are involved in the correct manner, the number of steps can be reduced, saving labor and reducing the possibility of making a mistake.

....

Example...**5a**
Find the value of $\frac{7.24 \times 8.51}{91.5}$

Solution...
For the simplest method, first divide 7.24 by 91.5 and then multiply by 8.51, as follows:

(1) Push hairline to 724 on scale D.
(2) Move slide so that 915 on scale C is under the hairline.
(3) Push hairline to 851 on scale C.
(4) Under hairline on scale D read, 673, the digits of the answer.

To locate decimal point: $\frac{7 \times 8}{100} = 0.56$. Hence, the answer will be 0.673.

Explanation...
Fig. 15 illustrates this problem. The dashed vertical line indicates the first position of the hairline, in which 724 on scale D is opposite 915 on scale C. The solid vertical line

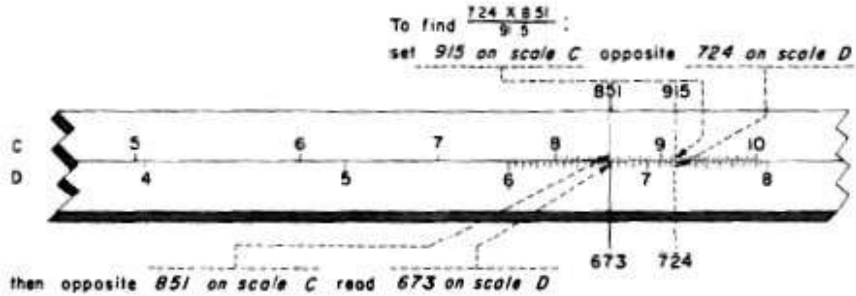


Fig. 15. Finding $\frac{7.24 \times 8.51}{91.5} = 0.673$

represents the second position of the hairline, where it is placed over 851 on scale C and reads the answer 673 on scale D.

To understand how the steps of the solution result in the answer for $\frac{724}{915} \times 851$, first divide 724 by 915 in the regular manner, writing down the answer 791. To get the answer to the problem, 791 must now be multiplied by 851. To do this the right index of scale C is placed opposite 791 on scale D. Providing the slide was not moved after writing down the value 791, it will be found that the right index of scale C is already opposite 791 on scale D. Thus, no resetting of the slide is necessary, it being already in the proper position. Hence, the step where the index of the C scale is set opposite the quotient of 724/915 on the D scale can be entirely eliminated, the slide already being in its proper position. For the same reason it is not necessary to read or to consider the quotient of 724/915. With this unnecessary work eliminated the problem reduces to the four steps given under the solution above.

In order for you to see the importance of working problems in the proper order where several factors are involved, you should rework Example 5 above by first multiplying 724 by 851, and then dividing by 915. You will find that the slide must be set twice when the problem is worked in this manner, thus making considerably more work, and increasing the chances of making a mistake. Also, the accuracy is reduced to some extent, because the more times the slide must be set the less the final accuracy. That is because any setting of the slide is subject to a certain amount of error, so that the more the slide is set the greater the total error. However, even with many settings this error should be small with proper care.

By the method of Example 5(a) the combined resistance of two resistors in parallel can be found quickly by using the formula,

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

. . . .

Example... **5b**

What is the combined resistance of 23 ohms and 30 ohms in parallel?

Solution... See Fig. 16

(1) Set hairline over 30 on scale D.
(2) Mentally add 23 to 30 giving 53. Move slide so that 53 on scale C is under the hairline.
(3) Move hairline over 23 on scale C.
(4) Read the figures of the result, 1302, under the hairline on scale D.
(5) To locate the decimal point we make use of the rule that the combined resistance of two resistors in parallel is always less than that of the smaller of the two resistors, but never less than half the resistance of the smaller resistor.

Hence, in this case the resistance must be less than 23 ohms and greater than 11.5 ohms. The answer must then be 13.02 ohms or 13 ohms for all practical purposes.

Example 5(a) involves only three terms. When more than three are involved in a combined multiplication and division problem, the problem is worked by an extension of the method above. The rule for working such problems with least labor and minimum settings of the slide is to divide first and then to alternately multiply and divide.

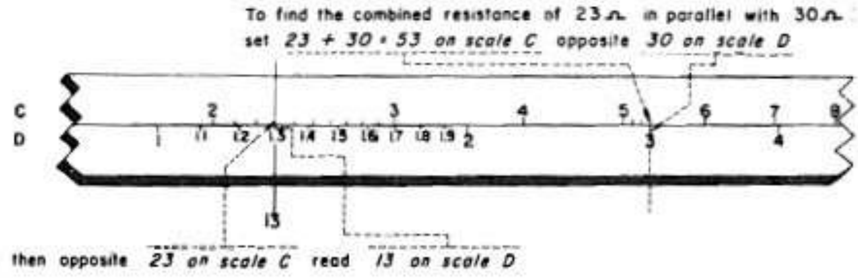


Fig. 16. Finding that the combined resistance of 23 ohms in parallel with 30 ohms is 13 ohms.

Example... 6

Find the value of $\frac{51.7 \times 23.1 \times 3.27}{42 \times 7.53}$

Solution...

First divide 517 by 42. Then multiply by 231. Follow this by dividing by 753, and then multiplying by 327. The problem could, of course, be worked equally well in some other order, just so you divide as the first step and then follow by alternately multiplying and dividing.

The work is as follows:

(1) Set hairline over 517 on scale D.
(2) Push slide so that 42 on scale C is under the hairline.
(3) Push hairline so that it is over 231 on scale C.
(4) Push slide so that 753 on scale C is under the hairline.
(5) Push hairline so that it is over 327 on scale C.
(6) Read the digits of the answer, 1235, under hairline on scale D.

To locate decimal points:

$$\frac{5\not{0} \times 20 \times 3}{4\not{0} \times 7} = \frac{300}{28} = \text{approx. } \frac{30\not{0}}{3\not{0}} = 10$$

Hence, the answer to the problem is 12.35.

Example 6 could just as well have been worked in some other order, just so a division is made first and that followed by alternately multiplying and dividing. As an exercise you should work the problem in some other order. As a further exercise, work the problem by first multiplying together the numerator factors, 517 × 231 × 327, then multiplying the denominator factors, 42 × 753, and then dividing the numerator product by the denominator product. You will find the labor by this method to be many times that of the proper method explained above. Also, you are much more apt to make a mistake. Yet you will find many technicians using their slide rules in this cumbersome manner.

. . . .

Example. . .7

Find the value of $\frac{87 \times 46.1}{72 \times 38.2}$

Solution. . .

First divide 87 by 72, then multiply by 461, and then divide by 382, as follows:

(1) Push hairline so that it is over 87 on scale D.
(2) Push slide so that 72 on scale C is under the hairline.
(3) Push hairline so that it is over 461 on scale C.
(4) Push slide so that 382 on scale C is under the hairline.
(5) Read the digits of the answer, 1458, opposite the left index of scale C.

To place decimal point:

$$\frac{9\not{0}}{7\not{0}} \times \frac{5\not{0}}{4\not{0}} = \frac{45}{28} = 2^{-}$$

where 2^{-} means a value less than 2. Hence, the answer to the problem is 1.458.

Explanation. . .

The difference between this problem and Examples 5(a) and 6 is that the last step in this problem is one of division. Hence, you read the answer opposite the index of C, the same as you would for any ordinary division problem.

. . . .

17 RESETTING THE SLIDE... In working any combination problem it sometimes happens that an operation cannot be performed because the part of the slide that must be used is projecting beyond the body of the rule. This difficulty is overcome by a process called resetting the slide. This is done by pushing the hairline so that it is over the C-scale index that is within the body of the rule, in order to mark the position of that index.

Then the slide is pushed so that the C-scale index that was projecting beyond the body of the rule is now brought under the hairline; that is, it takes the place originally occupied by the other index. For example, in Fig. 17(a) the left index of scale C is opposite 6 on scale D. To reset the slide, push the slide so that the right index of scale C is opposite 6, as in Fig. 17(b).

Resetting the slide will never invalidate the answer to any problem. Therefore it may be used without hesitation in a problem whenever necessary in order to proceed with the following steps of the problem.

....

Example... 8
Find the value of $\frac{62.9 \times 7.4}{3.5}$

Solution...

(1) Set hairline over 629 on scale D.
(2) Push slide so that 35 on scale C is under the hairline. The next step would normally be to push the hairline so that it is over 74 on scale C. However, this is impossible with the slide in its present position. Therefore the slide must be reset.
(3) Reset slide, as follows:
  (a) Push hairline over left index of scale C.
  (b) Push slide so that right index of scale C is under hairline.
(4) Push hairline over 74 on scale C.
(5) Read the digits of the answer, 1330, on scale D.

To place decimal point: $\frac{60 \times \overset{2}{\cancel{7}}}{\cancel{3.5}} = 120$. Hence, the answer to the problem is 133.0.

. . . .

Resetting of the slide can often be avoided by changing the order of working the problem. Take, for example, the problem $\frac{194 \times 16.5 \times 7.4}{4.71 \times 39}$. Working in the usual manner, 194 is first divided by 471 and then multiplied by 165. However, it is found that the slide must be reset in order to multiply by 165. However, we can multiply by 74 without resetting, and this should be done, saving the factor 165 until later. That is, divide 194 by 471 and then multiply by 74. Follow this by dividing by 39 and then multiplying by 165, giving 129.0 as the answer. Thus, no resetting of the slide is necessary in this problem.

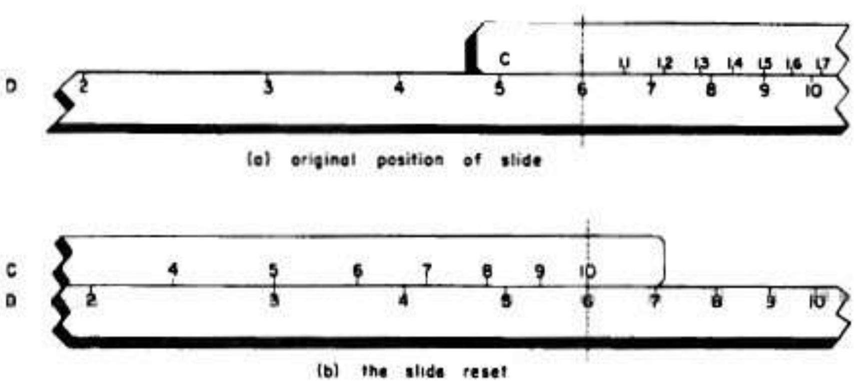


Fig. 17. When the part of the slide to be used for the next operation lies beyond the body of the rule, the slide is reset.

WHAT HAVE YOU LEARNED?

In order that you can check to see if you are working the following problems in the most efficient manner, the minimum number of slide settings for each problem is given in the answers.

1... $\frac{534 \times 6.1}{0.73} = ?$

2... $\frac{8.66 \times 420}{9.39} = ?$

3... $\frac{4.38 \times 212}{62.6} = ?$

4... $\frac{0.237 \times 1621}{43.2} = ?$

5... $\frac{284 \times 0.861}{5030} = ?$

6... $\frac{19 \times 44 \times 35.2}{24 \times 28} = ?$

7... $\frac{3400 \times 9.77 \times 16}{1.256 \times 556} = ?$

8... $\frac{0.001622 \times 84.4 \times 63}{33 \times 58} = ?$

9... $\frac{1.818 \times 0.079 \times 26.6}{23.4 \times 0.52} = ?$

10... $\frac{6830 \times 7.5}{2.99 \times 0.169} = ?$

11... $\frac{11.274 \times 3.53}{0.0382 \times 320} = ?$

12... $\frac{66.7 \times 1490}{6800 \times 204,600} = ?$

ANSWERS

Answer	Minimum slide settings	Answer	Minimum sli settings
1. 4460	1	7. 761	2
2. 388	1	8. 0.00451	2
3. 14.84	1	9. 0.314	2
4. 8.89	2	10. 101,400	3
5. 0.0486	1	11. 3.25	2
6. 43.8	2	12. 7.14×10^{-5}	2

18 **HANDLING SEVERAL FACTORS WITH CI SCALE...** We have found that the most efficient way to work problems involving more than two factors is first to divide and then to alternately multiply and divide. This process cannot be carried all the way through the problem unless the number of factors in the denominator is equal to or is one less than the number of factors in the numerator. However, when this is not the case, it is a simple matter to change the problem so that the factors are properly balanced between numerator and denominator for most efficient handling.

Suppose, for example, that we wish to evaluate $\frac{32}{26 \times 57}$. This cannot be done efficiently by the method so far explained, because it would require two divisions to be done consecutively. However, we can rewrite the problem to read, $\frac{32 \times \frac{1}{57}}{26}$. Dividing by a number is the same as multiplying by the reciprocal of that number. Hence, rather than divide by 57, we can multiply by $\frac{1}{57}$. Since the CI scale is a scale of reciprocals, to set up $\frac{1}{57}$ we set up 57 on the CI scale. To work this problem then, start in the regular manner by dividing 32 by 26. Then push the hairline so that it is over 57 on scale CI. Under the hairline read the answer, 0.0216, on scale D. The following rule takes care of all situations involving several factors:

➤ Rule... In problems in multiplication and division involving several factors, a division should be performed first, and this followed by alternate multiplication and division. If when a multiplication is required by this rule and no unused factor is left in the numerator, then a factor from the denominator may be used by setting its value on the CI scale. Or if a division is required by this rule and no unused factor is left in the denominator, a factor in the numerator may be used on the CI scale.

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Example... 9

Find the value of 716 × 0.203 × 6.7

Solution...

The method is to divide 716 by the reciprocal of 203 (which gives the same result as multiplying by 203) and then multiply by 67.

(1) Set the hairline over 716 on scale D.
(2) Push the slide so that 203 on scale CI is under the hairline.
(3) Push the hairline so that it is over 67 on scale C.
(4) Read the answer, 974, under the hairline on scale D.

Example... **10**

Find the value of $\frac{17}{64 \times 6.1 \times 24 \times 1.26}$

Solution...

(1) Set the hairline over 17 on scale D.

(2) Push the slide until 64 on scale C is under the hairline. We have now divided 17 by 64. If we try to multiply by the reciprocal of 6.1 as the next step we find that the slide must be reset because 6.1 on scale CI projects beyond the body of the rule. To avoid resetting the slide, we multiply by the reciprocal of 24 instead.

(3) Push the hairline so it is over 24 on scale CI.

(4) Push the slide so that 61 on scale C is under the hairline.

(5) Push the hairline over 126 on scale CI.

(6) Read the answer, 0.00144, on scale D.

Explanation...

The actual form of the problem as the slide rule works it is as follows:

$$\frac{17 \times \frac{1}{24} \times \frac{1}{126}}{64 \times 61}$$

The method is the same as in Example 6 and similar problems except that reciprocal values are set on the CI scale.

Example...**11**

Find the value of $\frac{1}{55.3 \times 27}$

Solution...

The method is to divide 1 by 55.3 and then multiply by the reciprocal of 27.

(1) Set hairline to 1 on scale D (that will be the right index of scale D).

(2) Push slide so that 55.3 on scale C is under the hairline.

(3) Push hairline over 27 on scale CI.

(4) Read the answer 0.000670 on scale D under the hairline.

Explanation...
In step 1 the hairline could have been set to either the right or the left index of scale D, since both represent the number 1. However, if the left index was used it would be necessary to reset the slide to obtain the answer to the problem. It is difficult for a beginner to know which index to select for the shortest solution. However, with some experience it is usually easy to tell which index is best.

....

WHAT HAVE YOU LEARNED?

1... $2.71 \times 6.42 \times 5.21 = ?$

2... $\dfrac{23.1}{251 \times 33.1} = ?$

3... $\dfrac{473}{2.75 \times 8.5} = ?$

4... $\dfrac{432}{2.81 \times 2.67} = ?$

5... $\dfrac{24 \times 68 \times 57 \times 49}{32.7} = ?$

6... $84.4 \times 0.00701 \times 9.89 \times 8.9 = ?$

7... $\dfrac{0.53 \times 4.5 \times 50.9}{13.2} = ?$

8... $\dfrac{1}{4.8 \times 0.0214} = ?$

9... $\dfrac{1}{0.047 \times 25.1 \times 0.563} = ?$

10... $\dfrac{45 \times 46 \times 57}{48 \times 49 \times 50 \times 51} = ?$

ANSWERS

1. 90.6 2. 0.00278 3. 20.2 4. 57.6 5. 139,400
6. 52.1 7. 9.20 8. 9.74 9. 1.506 10. 0.01967

19 SOLVING PRACTICAL PROBLEMS WITH THE SLIDE RULE...

In working a practical problem with the slide rule, the various operations that must be performed to obtain the answer should be written down before any calculations are made. Then the required operations can be performed as a single problem on the slide rule, thus making most efficient use of the rule. You have already learned how the slide rule saves the most labor in problems that involve a number of operations.

Example. . . 12

How many feet of wire will be required to wind 168 turns on a form 3.8 inches in diameter?

Solution. . .

The first thing to do is to find the length of one turn. Since the circumference of a circle is equal to the diameter multiplied by π, the length of one turn will be 3.8×3.14 inches.

To find the total length of the wire the length of one turn should be multiplied by the number of turns, giving $3.8 \times 3.14 \times 168$ inches as the total length of wire. This value must be divided by 12 to find the length of wire in feet. Hence, the complete problem becomes:

$$\frac{3.8 \times 3.14 \times 168}{12}$$

Solving with the slide rule gives 167 feet as the answer to the problem.

WHAT HAVE YOU LEARNED?

Work the following problems by writing down the complete problem before making any calculations.

1. . . A dc motor draws 23 amps at 440 volts. What is the horsepower input to the motor? The reverse side of your slide rule will tell you the number of watts in a horsepower.

2. . . The plate input to a vacuum tube is 1.7 amps at 650 volts. The efficiency of the tube is 55%. What is the power output from the stage?

3. . . Two resistors are in series. The voltage across the first resistor is 78 volts, and the resistance is 425 ohms. The resistance of the second resistor is 167 ohms. What is the voltage across the second resistor?

4... The voltage across a resistance of 6,300 ohms is 83 volts. Find the peak value of the current through this resistor.

ANSWERS

1. $P = \frac{23 \times 440}{746} = 13.57$ horsepower, ans.

2. $P = 1.7 \times 650 \times 0.55 = 608$ watts, ans.

3. $E_2 = \frac{78 \times 167}{425} = 30.6$ volts, ans.

4. $I_m = \frac{83 \times 1.414}{6300} = 0.01863$ amps, ans.

20 REPEATED OPERATIONS WITH ONE FACTOR CONSTANT...

It frequently occurs in electronics that a number of values must be multiplied or divided by some constant factor. The slide rule is particularly adaptable to this type of work.

....

Example...13

In a series of measurements on certain equipment the following effective voltage values were obtained: 133 volts, 268 volts, 431 volts, 740 volts, and 806 volts. It is desired to know the peak values of these voltages.

Solution...

The peak voltages are found by multiplying the effective values by 1.414.

(1) Set the left index of the C scale opposite 1.414 on scale D.

(2) Opposite 133 on scale C read 188.1 volts on scale D, the peak value of 133 volts.

(3) Similarly, opposite 268 on scale C read 379 peak volts on scale D, and opposite 431 on scale C read 609 on scale D.

(4) To read the peak values corresponding to 740 and 806 volts, reset the slide.

(5) Opposite 740 and 806 on scale C read the corresponding peak values, 1046 and 1140 volts.

. . . .

Example 13 shows that to multiply several values by a common factor only one or two movements of the slide is required. Repeated operations in division involving a common factor should be changed to a problem in multiplication so as to retain the advantage of a single (or possibly two) settings of the slide.

. . . .

Example. . . **14**

The length of five antennas are 31.5 meters, 40.2 meters, 47.1 meters, 50.1 meters, and 52.3 meters. Find the length of these antennas in feet.

Solution. . .

The back of the slide rule shows that one foot is equal to 0.3048 or about 0.305 meter. Hence, each of the antenna lengths must be divided by 0.305 to get their lengths in feet. Dividing in the regular way it is found that the slide must be changed for each value to be read. This can be avoided by changing the problem to one in multiplication.

To do this remember that dividing by 0.305 is the same as multiplying by the reciprocal of 0.305. By using the C and CI scale as explained in Topic 15 the reciprocal of 0.305 can be found to be 3.28. Hence, by setting the right index of the C scale opposite 3.28 on scale D, we can directly read off the required values as in Example 13. However, there is a quicker way to get the slide in the proper position, as follows:

Find the reciprocal of 0.305 by dividing 1 by 0.305. To do this:

(a) Move the slide so that 0.305 on scale C is opposite 1 (the left index) on scale D.

(b) Notice that the right index of scale C is now opposite 3.28, the reciprocal of 0.305, on scale D. Hence, no further adjustment of the slide is necessary.

Opposite the values in meters on scale C read the required values in feet on scale D, giving the following: 31.5 meters = 103.3 feet. 40.2 meters = 131.9 feet. 47.1 meters = 154.5 feet, 50.1 meters = 164.3 feet, 52.3 meters = 171.5 feet, the required answers.

Example...15
Divide 291 consecutively by the values 35.3, 42.3 and 58.4.

Solution...
Dividing by these values is the same as multiplying by their reciprocals. Hence,

(1) Set the left index of scale C opposite 291 on scale D.
(2) Move hairline so that it is over 35.3 on scale CI.
(3) Under the hairline on scale D read 8.24 on scale D. This will be the value of 291 divided by 35.3.
(4) In the same manner opposite 42.3 and 58.4 on scale CI read 6.88 and 4.98 on scale D. Hence,

$$\frac{291}{42.3} = 6.88, \text{ and } \frac{291}{58.4} = 4.98.$$

....

WHAT HAVE YOU LEARNED?

Do not use more than two settings of the slide for any single computation in any of these problems.

1...Compile a table that will give the circumference of any circle with a diameter between one and three inches, the diameter being measured to the nearest quarter inch.

2...Change the following fractions to decimal forms:
1/64, 3/64, 9/64, 13/64, 17/64, 21/64, 23/64, 25/64.

3...There are 37 questions in an examination. If all are correct the grade is 100%. Assuming each question has equal weight, make a table showing the proper grade for any number of missed questions up to 10.

4...The voltage across a parallel circuit is 135 volts. Find the current values for circuit resistances of 220, 330, 440, 550, and 660 ohms.

ANSWERS

1.

Diameter	Circumference
1 in.	3.14 in.
1 1/4 in.	3.93 in.
1 1/2 in.	4.71 in.
1 3/4 in.	5.50 in.
2 in.	6.28 in.
2 1/4 in.	7.07 in.
2 1/2 in.	7.85 in.
2 3/4 in.	8.64 in.
3 in.	9.42 in.

2. 1/64 = 0.0156
3/64 = 0.0469
9/64 = 0.1406
13/64 = 0.203
17/64 = 0.266
21/64 = 0.328
23/64 = 0.359
25/64 = 0.391

3.

Questions missed	Grade	Questions missed	Grade
1	97.3%	6	83.8%
2	94.6%	7	81.1%
3	91.9%	8	78.4%
4	89.2%	9	75.7%
5	86.5%	10	73.0%

4.

Resistance	Current
220 ohms	614 milliamperes
330 ohms	409 milliamperes
440 ohms	307 milliamperes
550 ohms	245 milliamperes
660 ohms	205 milliamperes

21 SQUARES AND SQUARE ROOTS...The A and B scales are used in conjunction with the C and D scales for working problems involving squares and square roots. One way to find the square of a number, say of 1.6 is to multiply 1.6 by 1.6 in the regular way using the C and D scales. A quicker way is to move the hairline until it is over 1.6 on scale D and to then read the square, 2.56, under the hairline on scale A. See Fig. 18.

Since the A scale cannot be read with as great an accuracy as the C or D scales, this method is not used when the greatest possible accuracy is needed. However, it is accurate enough for most requirements.

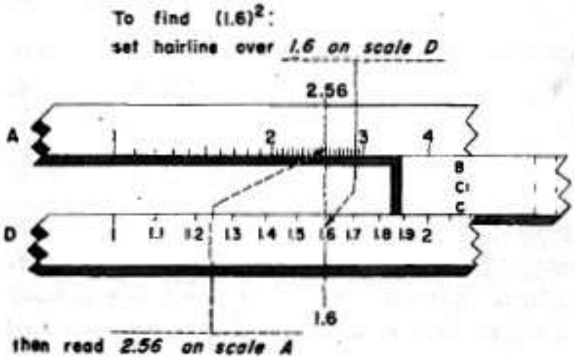

Fig. 18. Finding that $(1.6)^2 = 2.56$ (or finding that $\sqrt{2.56} = 1.6$).

Finding the square root is the reverse of finding the square of a value. In finding the square root the hairline is placed over the value of which the root is wanted on scale A, and then under the hairline on scale D the value of the root is read. For example to find the square root of 9, slide the hairline until it is over 9 on scale A, and then under the hairline on scale D read 3, the value of the square root of 9.

In all problems up to this time the location of the decimal point has been found by inspection after all slide rule manipulations were completed. In extracting the square root the position of the decimal point must always be considered before any work is done with the rule.

Since the decimal point must be considered, the slide rule is only directly suitable for finding square roots of numbers which are within the range of the A or B scale, which you will notice is from 1 to 100. However, it is very simple to adapt numbers below 1 or above 100 so that their roots may be obtained on the slide rule.

Example. . . **16**
Find the square root of 85.4.

Solution. . .
Since this value is between 1 and 100, it can be set up directly on the A scale.

(1) Move the hairline until it is over 85.4 on scale A. This value is near the right end of the A scale.
(2) Under the hairline on scale D read 9.24, ans.

Explanation. . .
The hairline must be set to 85.4 on the A scale, and not on 8.54. 85.4 is between the marks 80 and 90 near the right of the A scale. 8.54 would be between 8 and 9 near the center of the A scale. As an exercise you should extract the root of 8.54 on your slide rule, showing that the answer is 2.92.

When the number of which the root is wanted does not lie between 1 and 100, the number should first be divided off into periods of two digits, starting at the decimal point, exactly the same as when finding the square root arithmetically. Then extract the root on the slide rule considering the decimal point as being after the first period which is not zero in value.

Example. . . **17**
Find the square root of 71,400.

Solution. . .

(1) Divide into periods: 7'14'00. (Remember to start at the decimal point for this operation.)
(2) Consider the decimal point as being at the end of the first period; that is, after the 7.
(3) Find the square root of 7.14: Move hairline so that it is over 7.14 on scale A and then read the root digits, 267, on scale D.

(4) To locate the decimal point use the rule that for numbers greater than 1 there will be as many digits to the left of the decimal point in the root as there are periods to the left of the decimal point. So the square root will have three digits to the left of the decimal point.

Hence, 267 is the answer.

Example...18

Find $\sqrt{0.0000315}$

Solution...

(1) Dividing into periods: 0.00'00'31'5
(2) Consider the decimal point as being at the end of the first period not zero in value; that is, after 31.
(3) Find the digits of the square root of 31.5 to be 561.
(4) To locate the decimal point use the rule that for numbers less than 1 there will be one zero immediately to the right of the decimal point in the answer for each period of zeros immediately to the right of the decimal point in the number. The number 0.00'00'31'5 has two periods of zero value immediately to the right of the decimal point.

Hence, 0.00561 is the root of this number.

....

WHAT HAVE YOU LEARNED?

1... $(0.873)^2$ = ?

2... $(46.5)^2$ = ?

3... $(6.25)^2$ = ?

4... $(0.001234)^2$ = ?

5... $\sqrt{4.235}$ = ?

6... $\sqrt{5}$ = ?

7... $\sqrt{50}$ = ?

8... $\sqrt{4}$ = ?

9... $\sqrt{40}$ = ?

10... $\sqrt{33.34}$ = ?

11... $\sqrt{0.5011}$ = ?

12... $\sqrt{754569}$ = ?

13... $\sqrt{250,000,000}$ = ?

14... $\sqrt{0.000383}$ = ?

15... $\sqrt{0.06}$ = ?

16... $\sqrt{846}$ = ?

ANSWERS

1. 0.762	5. 2.06	9. 6.32	13. 1.581×10
2. 2160	6. 2.24	10. 5.77	14. 1.957×10
3. 39.1	7. 7.07	11. 0.708	15. 0.245
4. 1.523×10^{-6}	8. 2.00	12. 869	16. 29.1

22 EVALUATING EXPRESSIONS CONTAINING SQUARES...

Wor ing problems on the slide rule where power or roots are i volved often require no more work than if the power or roo were not required. The following examples show how to hand problems involving powers and the next topic will cover pro lems involving roots.

....

Example... **19**

Find the value of $(19.4 \times 4.21)^2$

Solution...

Multiply 19.4 by 4.21 in the usual manner, but instead of rea ing the answer under the hairline on scale D, read the digits the answer, 667, on scale A instead. Reading on scale would give the product of 19.4×4.21, while reading on sc A will give $(19.4 \times 4.21)^2$. That is because the square of a value on scale D is given directly above on scale A. To cate the decimal point, note that $20 \times 4 = 80$, and $80^2 = 6,4$ Hence, the answer will be 6670.

Example... **20**

Find the value of $\left(\frac{19.4}{4.21}\right)^2$

Solution...

Divide 19.4 by 4.21 in the usual manner, but instead of reading the answer on scale D opposite the right index of scale C, read the answer, 21.2, on scale A opposite the right index of scale B. The principle here is the same as for Example 19. We want the square of the result obtained by division; therefore, we read from scale A rather than from scale D.

....

The following example, as well as many other problems to follow, makes use of the fact that the A and B scales can be used for ordinary multiplying and dividing, just as can the C and D scales. An A or B scale is nothing more than a C or D scale reduced to half-size, so that it can be repeated twice on the rule.

....

Example... **21**

Find the value of $4.4 \times (1.34)^2$.

Solution...

(1) Set the left index of the C scale opposite 1.34 on scale D.
(2) Push the hairline so that it is over 44 or 4.4 on scale B.
(3) Under the hairline on scale A read the answer digits, 790.
(4) Locating the decimal point gives 7.90 as the answer.

Explanation...

In step (1) by setting the left index of C opposite 1.34 on scale D, the left index of B is placed opposite 1.34^2 on scale A. We now use the A and B scales to multiply together the two values 4.4 and 134^2. Since the left index of B is already opposite 134^2 it is only necessary to set the hairline to 44 on scale B and read the answer on scale A.

In step (2) notice that there are two different positions on scale

B where the hairline is over 44, one on the left half on the B scale and the other on the right half of the scale. Either position may be used. It is only in extracting the square root that the proper half of the A or B scale must be chosen.

Example... **22**
Find the value of $\frac{(8.2)^2}{3.14}$

Solution...

(1) Set hairline over 82 on scale D.
(2) Move slide so that 314 on either half of scale B is under the hairline.
(3) Read digits of answer, 214, opposite left index of B on scale A.

Explanation...
Setting the hairline over 82 on scale D at the same time places it over 82^2 on scale A. We now divide 82^2 by 3.14 in the usual manner, except that we use the A and B scale for the purpose, and the value 82^2 has already been set on scale A. The answer is 21.4.

Example... **23**
Find the value of $\frac{8.2}{(3.14)^2}$

Solution...

(1) Set the hairline over either 82 on scale A.
(2) Move slide until 314 on scale C is under the hairline.
(3) Read answer digits, 832, opposite an index of scale B on scale A.
(4) Locating decimal point the answer is 0.832.

Explanation...
This is another problem in dividing using the A and B scales. In step (2) we want $(314)^2$ under the hairline on the B scale. By placing 314 on the C scale under the hairline, we at once have 314^2 on scale B under the hairline.

. . . .

1... $(7.1 \times 0.734)^2 = ?$

2... $(0.0239 \times 560)^2 = ?$

3... $(41)^2 \times (0.56)^2 = ?$ [This expression is equivalent to $(41 \times 0.56)^2$]

4... $\left(\frac{148.5}{50.4}\right)^2 = ?$

5... $\left(\frac{0.616}{0.818}\right)^2 = ?$

6... $\frac{(66.9)^2}{(14.6)^2} = ?$ [This expression is equivalent to $\left(\frac{66.9}{14.6}\right)^2$]

7... $9.26 \times (4.48)^2 = ?$

8... $(4.93)^2 \times 0.86 = ?$

9... $\frac{(5.33)^2}{45.6} = ?$

10... $\frac{(0.97)^2}{18.839} = ?$

11... $\frac{75}{(9.18)^2} = ?$

12... $\frac{8.41}{(1.61)^2} = ?$

13... $\frac{1}{(0.467)^2} = ?$ (explain in answer this is equal to $\left(\frac{1}{0.467}\right)^2$

14... Find the reciprocal of $(4.67)^2$.

15... Using the formula $P = I^2R$, find the power when I is equal to 0.32 amps and R is equal to 68 ohms.

16... Using the formula $P = E^2/R$, find the power when E is equal to 125 volts and R is equal to 47,000 ohms.

17... Using the formula $R = \frac{P}{I^2}$, find the resistance when P is equal to 5 watts and I is equal to 36 milliamperes.

1. 27.2	7. 185.9	13. 4.59
2. 179.1	8. 20.9	14. 0.0459
3. 527	9. 0.623	15. 6.96 watts
4. 8.68	10. 4.99×10^{-2}	16. 0.332 watt
5. 0.566	11. 0.889	17. 3,860 ohms
6. 21.0	12. 3.24	

23 EVALUATING EXPRESSIONS CONTAINING SQUARE ROOTS ...The examples of Topic 22 show that the general method in problems involving squares is to set the values to be squared on the C or D scales so that the squares appear on the A or B scales. The succeeding operations involving multiplication or division are then carried on using the A and B scales, and the final answers are read on the A scale.

In problems involving square roots the general method is just the reverse of this. Values for which the square roots are needed are set on the A or B scales, so that the roots appear on the C or D scales. Any further operations are then performed with the C and D scales, and the final answer read on the D scale.

In problems involving squares the final digit is read on the A scale. Because of this there is a certain sacrifice in accuracy since the A scale, being condensed, cannot be read as accurately as can the D scale. If this loss of accuracy is objectionable, it can be avoided by multiplying the number to be squared by itself using the regular method for multiplying two numbers. In this manner the entire problem is worked on the C and D scales, so there is no loss in accuracy. Problems involving square roots do not suffer in accuracy through the use of the A and B scales because the final answer is read on the D scale, which is a full length scale.

While the decimal point need not be considered during the slide rule manipulations with problems involving squares, when square roots are involved, it is essential to consider the decimal whenever a root is extracted.

....

Example... 24

Find $\sqrt{14 \times 2.7}$

Solution...

14 is multiplied by 2.7 using the A and B scales, and then the square root is read on the D scale.

(1) Set the left index of scale B opposite 14 on scale A. Not considering the decimal point, 14 appears twice on scale A, once on each half of scale. Use the 14 on the left scale, so that the slide will project a minimum amount from the body of the rule. In some cases this will save resetting the slide.

(2) Move the hairline so that it is over 27 on scale B. Under the hairline on scale A is the product of 14 × 27. This need not be read however, because it is the square root of this product and not the product itself that is wanted. There are two positions on scale B where the hairline will be over 27. Either position will give the same value for the product. But since the square root of the product is wanted, the position of the decimal point must be considered. 14 × 2.7 is roughly equal to 15 × 3 or 45. Hence, the proper position of the hairline is over the 27 on scale B that will put the product on the right half of scale A. This means the hairline should be over 27 on the right half of scale B.

(3) Read the digits of the answer, 615, on scale D under the hairline.

(4) Since the answer is roughly equal to the square root of 45 (found in step 2), the answer must be 6.15.

Example... 25

Find the value of $0.707 \times \sqrt{41.5}$

Solution...

The square root of 41.5 is first found, and this result multiplied by 0.707. Fig. 19 shows the set up for this problem.

(1) Set the right index of scale B opposite 41.5 of the right-hand section of scale A.

(2) Move hairline over 707 on scale C.

(3) Read the digits of the answer, 455, under the hairline on scale D.

(4) Locate the decimal point by noting that the square root of 41.5 is about 6, and that 6 × 0.7 is about 4. Hence, the answer is 4.55.

Explanation...

When the right index of scale B is set opposite 41.5 on scale A, the right index of scale C is opposite $\sqrt{41.5}$ on scale D. Hence, the slide is in the proper position for multiplying this value by any number.

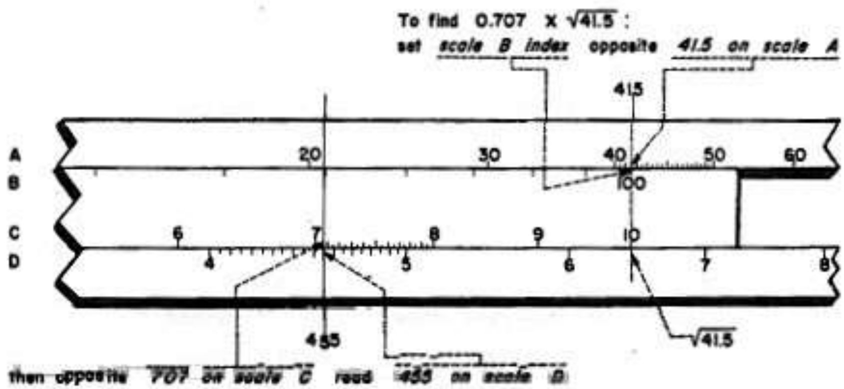

Fig. 19. Finding $0.707 \times \sqrt{41.5} = 4.55$.

Example...26

Find $\frac{\sqrt{3.9}}{\pi}$

Solution...

(1) Set hairline over 3.9 on the left half of scale A.

(2) $\sqrt{3.9}$ is now under the hairline on scale D. To divide this by π, move the slide so that π (3.14)

on scale C is under the hairline.

(3) Read the digits of the answer, 629, on scale D opposite the right index of scale C.

(4) To locate the decimal point note that $\sqrt{3.9}$ is about equal to $\sqrt{4}$, which is 2. $2/\pi$ is about equal to 2/3 or 0.6.

Hence, the answer is 0.629.

Example... **27**

Find $\frac{\pi}{\sqrt{3.9}}$

Solution...

Notice that this is the reciprocal of the problem of Example 26. Except for reading off the final result this problem is worked exactly like that of Example 26. In Example 26 the answer is read on scale D opposite the index of scale C. In Example 27 we do not want this value but its reciprocal. To find it read the digits 1592 on scale C opposite the left index of scale D. Locating the decimal point gives 1.592 as the answer. For any setting of the slide a reading on scale C opposite the D index is always the reciprocal of the reading on scale D opposite the C index, and vice versa.

....

Example 27 illustrates the general method of handling problems where a square root is in the denominator but not in the numerator. Invert the problem so that the square root will be in the numerator. Then solve the problem in a manner similar to that of Example 26, but read the answer on scale C rather than scale D.

....

Example... **28**

Find $\frac{1}{\sqrt{5.5}}$

Solution...

What is wanted is the reciprocal of $\sqrt{5.5}$.

(1) Set the hairline over 5.5 on the left half of scale B.

(2) $\sqrt{5.5}$ now appears under the hairline on scale C, and the reciprocal of $\sqrt{5.5}$ under the hairline on scale CI. Read 0.426 on scale CI, the answer.

Example... 29

Find $\frac{31.5}{\sqrt{4.04 \times 3.03}}$

Solution...

As explained under Example 27, this problem should be changed to one of finding the reciprocal of $\frac{\sqrt{4.04 \times 3.03}}{31.5}$.

(1) Set left index of B opposite 404 on the left half of scale A.

(2) Set hairline over 303 on scale B. The product of 404 by 303 now appears on scale A under the hairline and providing the correct half of the A scale is being used, the square root of this product is under the hairline on scale D. 4.04 × 3.03 is about 12. Hence, the correct position for the hairline for extracting the square root is on the right half on scale A. As it is now in this position, $\sqrt{4.04 \times 3.03}$ is under the hairline on scale D.

(3) Move the slide so that 315 on scale C is under the hairline.

(4) Since the reciprocal is wanted, read 899 on scale C opposite the right index of scale D, rather than reading opposite the left index of scale C on scale D.

(5) Locating the decimal point gives 8.99 as the answer.

....

WHAT HAVE YOU LEARNED?

1... $\sqrt{4.31 \times 6.67}$ = ? 2... $\sqrt{0.511 \times 4270}$ = ?

3... $\frac{\sqrt{21.1 \times 33.5}}{2.88} = ?$

4... $325 \times \sqrt{60} = ?$

5... $\sqrt{1.114} \times 0.77 = ?$

6... $\frac{\sqrt{37}}{14} = ?$

7... $\sqrt{\frac{228}{8.7}} = ?$

8... $\frac{91.1}{\sqrt{6.4}} = ?$

9... $\frac{1}{\sqrt{35}} = ?$

10... $\frac{1000}{\sqrt{3.5}} = ?$

11... $\frac{\sqrt{44 \times 77}}{37} = ?$

12... $\frac{\sqrt{0.188 \times 4.8}}{0.0576} = ?$

13...Using the formula, $I = \sqrt{\frac{P}{R}}$, find the value of I when P is equal to 40 watts, and R is equal to 4.5 ohms.

14...Using the formula, $E = \sqrt{PR}$, find the value of E when P is equal to 3.5 watts and R is equal to 6,800 ohms.

15...Using the formula, $f = \frac{159,000}{\sqrt{LC}}$, where f is in kc, L is in μh, and C is in μμf, find the value of f when L is equal to 350 μh and C is equal to 475 μμf.

ANSWERS

1.	5.36	6.	0.434	11.	1.573
2.	46.7	7.	5.12	12.	16.49
3.	9.22	8.	36.0	13.	2.98 amperes
4.	2520	9.	0.169	14.	154.3 volts
5.	0.813	10.	535.0	15.	390 kc

24 PROPORTION...Problems in proportion are easily solved on the slide rule. A proportion is usually written in the form,

$$\frac{a}{b} = \frac{c}{X}$$

where the values of a, b, and c are known, and X is the value it is desired to find. X is not necessarily in the position shown, but can equally well be in any of the other three positions represented by a, b, and c.

To solve problems in proportion the line or narrow gap between the C and D scales that separates the slide from the lower body member may be assumed to represent the line dividing the numerators from the denominators in the terms of a proportion. Thus in the proportion above the numerator values, a and c, are set on scale C, while the denominator values, b and X, are set on scale D.

....

Example. . . 30
Find the value of X in the proportion, $\frac{43}{X} = \frac{20.4}{69}$

Solution. . .
43 and 20.4, being numerator values, are set up on scale C while the denominator values, 69 and X, appear on scale D.

(1) Set 20.4 on scale C opposite 69 on scale D. This is easiest to do if the hairline is first set to 69 on scale D.
(2) Opposite 43 on scale C read the figures for the value of X, 1455, on scale D. In this particular problem the slide must be reset (See Topic 17) before this reading can be made.
(3) To locate the decimal point note that 69 is about three times 20.4. Then X will be about three times 43.

Hence, the value of X must be 145.4, ans.

....

WHAT HAVE YOU LEARNED?

Solve for X:

1... $\frac{12}{25.3} = \frac{X}{11}$ 2... $\frac{35}{55} = \frac{150}{X}$

3... $\frac{X}{82} = \frac{45}{18}$ 4... $\frac{70}{X} = \frac{0.15}{0.25}$

5... The reactance of an inductor is proportional to the frequency. If the reactance of a certain inductance is 1500 ohms at 2100 cps, what will the reactance be at 1200 cps?

6... If a train travels 378 miles in 11 hours, how far will it travel in 17 hours?

7... The voltage ratio between the primary and the secondary of a transformer varies directly with the turns ratio. If the primary of a transformer contains 500 turns and has 110 volts impressed on it, and the secondary has 23,000 turns, what voltage would be delivered by the secondary?

8... If 16½ feet of coaxial transmission line costs $61.87, find the cost of 28 feet at the same rate.

ANSWERS

1.	5.22	5.	857 ohms
2.	236	6.	584 miles
3.	205	7.	5060 volts
4.	116.7	8.	$105.00

LESSON 3123-1

SLIDE RULE

EXAMINATION

Circle the number of the correct answer for each question that follows. Then transfer the answers to the answer sheet by putting X's in the proper squares. When the graded answer sheet is returned to you, correct in this book any questions you may have missed. You will then have a record of the correct answers to all questions.

1. An important use of the CI scale is
   1. as an aid in finding the combined resistance of two resistors in parallel.
   2. to reduce the number of slide settings required in combined multiplication and division problems.
   3. to reduce the need for resetting the slide due to running off the end of the rule.
   4. none of the above.

2. If the resistance of a circuit is 128.4 ohms, what is the circuit conductance?
   1. 0.000776 mho 2. 0.000778 mho 3. 0.00776 mho 4. 0.00779 mho 5. 0.00781 mho

3. The best way to find the combined resistance of 240 ohms in parallel with 460 ohms involves
   1. using the CI and the C scales
   2. using the CI and the D scales
   3. using the CI and C and the D scales
   4 using the C and D scales

4. We can easily place the decimal point in finding the combined resistance of two resistors in parallel by noting that the combined resistance is
   1. always somewhere between the resistance of the smaller resistor and one-half that value.
   2. between the value of the smaller and the larger resistor.
   3. roughly equal to the sum of the two resistances divided by two.
   4. roughly equal to the sum of the two resistances divided by four.

5. What is the combined resistance of 240 ohms in parallel with 460 ohms?

1. 15.8 ohms	2. 134.3 ohms	3. 157.7 ohms
4. 320 ohms	4. 522 ohms	6. 1587 ohms

6. To find the value of $\frac{352 \times 522}{455}$ you can best

   1. set 352 on the C scale opposite 522 on the D scale and then read answer on D scale opposite 455 on C scale
   2. set 352 on the C scale opposite 455 on the D scale, and then read answer on D scale opposite 522 on C scale.
   3. set 455 on the C scale opposite 352 on the D scale and then read answer on D scale opposite 522 on C scale.
   4. set 455 on the CI scale opposite 352 on the D scale, and then read the answer on D scale opposite 522 on C scale.
   5. set 522 on the CI scale opposite 352 on the D scale, and then read the answer on D scale opposite 455 on CI scale.
   6. set 522 on the CI scale opposite 352 on D scale, and then read answer on C scale opposite 455 on the D scale.
   7. set 352 on the C scale opposite 522 on the D scale, and then read answer on D scale opposite 455 on CI scale.
   8. set 522 on scale C opposite right index of scale D. Set hairline over 352 on CI scale. Move slide so that 455 on scale C is under the hairline. Read answer on scale D opposite scale C index.

7. To find the value of 352 × 455 × 522 you can best (Select answer from choices for Ques. 6).

8. To find the value of $\frac{522}{352 \times 455}$ you can best (Select answer from choices for Ques. 6)

9. To find the value of $\frac{1}{352 \times 455 \times 522}$ you can best (Select answers from choices for Ques. 6)

10. The reactance of an inductor is proportional to the frequency. If the reactance of a certain inductor is 48,000 ohms at 456 kc, what is its reactance at 25 kc.

1. 262 ohms	2. 875 ohms	3 2630 ohms
4. 8750 ohms	5. 26,400 ohms	6. 87,500 ohms

11. Using the formula $I = \sqrt{P/R}$, find the maximum current that a resistor with a wattage rating of 4 watts and a resistance of 2460 ohms can carry without overheating.

1. 0.01276 ma 2. 0.404 ma 3. 5.04 ma
4. 12.76 ma 5. 40.4 ma 6. 127.6 ma

12. Using the formula $P = I^2R$, what is the power dissipation from a 2160 ohm resistor carrying 35 ma?

1. 0.1875 watts 2. 1.28 watts 3. 1.875 watts
4. 2.64 watts 5. 12.8 watts 6. 26.4 watts

13. In a laboratory project you have obtained 25 peak voltage readings using an oscilloscope. You want to convert these 25 peak values to effective values by dividing each value by 1.414. How is the best way to do this?

1. Divide each value by 1.414 using the regular method of slide rule division.
2. Set slide rule so that indexes of C and D scales are opposite each other. Then move hairline so it is over 1.414 on CI scale. Next move right index of scale C so that it is under the hairline. Now without moving the slide again until all 25 conversions have been made, set the hairline over each peak voltage value in turn on the D scale and read the effective value on the C scale.
3. Set 1.414 on scale C opposite the left index of scale D. Set the hairline in turn over each peak voltage value on scale C to read the corresponding effective value on scale D.
4. Set 1.414 on scale C opposite the left index of scale D. Set hairline in turn over each peak voltage value on scale D and read the corresponding effective value on scale C.

END OF EXAM

Notes

Self-Analysis — If you're willing
to admit you're all wrong when you are, you're all right.

(Do not tear this page from your book, but cut at this dotted line.)

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